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PATENTS ACT 1977

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REQUEST FOR GRANT OF A PATENT

THE GRANT OF A PATENT IS REQUESTED BY THE UNDERSIGNED ON THE BASIS OF THE PRESENT APPLICATION

I Applicant's or Agent's Reference *(Please insert if available)* 32572G

II Title of Invention Gas Turbine Engine Fuel Control System and Regulating Valves therefore.

III Applicant or Applicants *(See note 2)*

Name (First or only applicant) Lucas Industries public limited company

Country United Kingdom State .... ADP Code No. ....

Address Great King Street, Birmingham, B19 2XF England.

Name (of second applicant, if more than one) ....

.... Country .... State ....

Address ....

IV Inventor (see note 3)

(a) ~~The applicant(s) is/are the sole/joint inventor(s)~~
or
(b) A statement on Patents Form No 7/77 is/will be furnished

V Name of Agent (if any) *(See note 4)* Marks and Clerk | ADP CODE NO

VI Address for Service (See note 5)

Alpha Tower, Suffolk Street Queensway, Birmingham, B1 1TT England.

VII Declaration of Priority (See note 6)

Country	Filing date	File number

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10 MAY 1989
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VIII The Application claims an earlier date under Section 8(3), 12(6), 15(4), or 37(4) (See note 7)

Earlier application or patent number .... and filing date ....

V4919

IX Check List *(To be filled in by applicant or agent)*

A	The application contains the following number of sheet(s)		B	The application as filed is accompanied by:-
1	Request 1	Sheet(s)	1	Priority document .... — ....
2	Description 13	Sheet(s)	2	Translation of priority document .... — ....
3	Claim(s) .... —	Sheet(s)	3	Request for Search .... — ....
4	Drawing(s) 7	Sheet(s)	4	Statement of Inventorship and Right to Grant .... — ....
5	Abstract .... —	Sheet(s)		

X It is suggested that Figure No — .... of the drawings (if any) should accompany the abstract when published.

XI Signature *(See note 8)* Marks & Clerk

NOTES:

1. This form, when completed, should be brought or sent to the Patent Office together with the prescribed fee and two copies of the description of the invention, and of any drawings.
2. Enter the name and address of each applicant. Names of individuals should be indicated in full and the surname or family name should be underlined. The names of all partners in a firm must be given in full. Bodies corporate should be designated by their corporate name and the country of incorporation and, where appropriate, the state of incorporation within that country should be entered where provided. Full corporate details, eg "a corporation organised and existing under the laws of the State of Delaware, United States of America," trading styles, eg "trading as xyz company", nationality, and former names, eg "formerly [known as] ABC Ltd." are not required and should not be given. Also enter applicant(s) ADP Code No. (if known).
3. Where the applicant or applicants is/are the sole inventor or the joint inventors, the declaration (a) to that effect at IV should be completed, and the alternative statement (b) deleted. If, however, this is not the case the declaration (a) should be struck out and a statement will then be required to be filed upon Patent Form No 7/77.
4. If the applicant has appointed an agent to act on his behalf, the agent's name and the address of his place of business should be indicated in the spaces available at V and VI. Also insert agent's ADP Code No. (if known) in the box provided.
5. An address for service in the United Kingdom to which all documents may be sent must be stated at VI. It is recommended that a telephone number be provided if an agent is not appointed.
6. The declaration of priority at VII should state the date of the previous filing and the country in which it was made and indicate the file number, if available.
7. When an application is made by virtue of section 8(3), 12(6), 15(4), or 37(4) the appropriate section should be identified at VIII and the number of the earlier application or any patent granted thereon identified.
8. Attention is directed to rules 90 and 106 of the Patent Rules 1982.
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GAS TURBINE ENGINE FUEL CONTROL SYSTEM AND REGULATING VALVES THEREFORE

This invention relates to valves for regulating fluid flows and fluid pressures, and to gas turbine engine fuel control systems incorporating such valves.

It is known to provide metering valves for fluids in which a control element is moved in response to variations in a servo-pressure, the servo-pressure being regulated by a valve which is energised by an electric force motor. It is a disadvantage of such known valves that failure of the force motor or its current supply may result in rapid change in the servo-pressure and consequent rapid movement of the valve control element away from its previously selected position. It is an object of one aspect of the invention to provide a metering valve arrangement in which this disadvantage is overcome.

According to one aspect of the invention there is provided a fluid flow control valve arrangement comprising a housing having an inlet and an outlet, a flow control element axially slidable in a bore in said housing to regulate flow between said inlet and outlet, a pilot valve having two outlet ports for applying pressures to respective opposite ends of said control element to position the latter, and a control member movable from a null position to increase the pressure at one of said ports and simultaneously to reduce the pressure at the other of said ports, said arrangement including two relief valves connected in parallel between one of said ports and a chamber at one end of said control element, said relief valves being spring biased and operable to permit flow in respective opposite directions, the pressure required to lift either of said relief valves being greater than a

pressure difference between said ports in a null position of the control member of said pilot valve.

Reheat systems for gas turbine engines are not normally operated for the whole time that the engine is running. Additionally, high engine operating temperature during reheat operation may cause the fuel in the reheat system to boil and to empty the system when reheat is shut off. If the system is allowed to empty, or partly empty, it will not respond sufficiently quickly when reheat is selected. It is an object of a further aspect of the invention to provide a reheat system in which the fuel supply manifolds are maintained primed with fuel at a pressure which is sufficient to prevent boiling.

According to another aspect of the invention there is provided a fuel control system for the reheat burners of a gas turbine engine, comprising a source of pressurized fuel, a plurality of metering valves for regulating fuel flow from said source to respective ones of a plurality of burner manifolds, a fuel supply device, and means operable when one of said metering valves is shut, for introducing pressurised fuel from said source into said manifolds.

One embodiment of the invention includes an auxilary source of pressurized fuel, a plurality of throttle valves between respective ones of said metering valves and their respective manifolds, one of said valves including ports which, when said one throttle valve is closed, connect said auxilary fuel source to the manifold associated with said one throttle valve.

In a preferred embodiment said one throttle valve is operable when closed to connect said auxiliary

fuel source to a further manifold of the system.

When a gas turbine engine main fuel system is shut down, heat flows from the engine or a rise in ambient temperature may expand fuel which is isolated between shut-off valves in a low pressure part of the fuel supply system, causing damage to that part of the system.

It is a still further object of the invention to provide a control valve for priming the engine reheat manifolds which will also act to relieve pressure in low pressure parts of the system when the engine is shut down.

According to a further aspect of the invention a valve for regulating pressure of a fluid comprises a housing having first and second ports for connection to a fluid pressure source and a lower pressure respectively, an outlet port and a control element movable between a first position in which said outlet port communicates with said first port and is isolated from said second port, and a second position in which said outlet port communicates with said second port and is isolated from said first port, a spring biassed plunger engageable with said control element to urge the latter towards said first position, said second port opening into a volume defined with said housing between said control element and said plunger, said control element being urged against said plunger and towards said second position by the pressure in said outlet port.

According to yet another aspect of the invention a fluid pressure control system comprises a fuel delivery passage, a pump for supplying fuel to said passage, a valve for regulating the pressure of fuel in

said passage, and a relief valve for venting fluid from said passage when the pressure therein exceeds a predetermined value, said valve comprising a housing having first and second ports communicating with the outlet and inlet respectively of said pump, an outlet port communicating with said delivery passage, a control element axially slidable in said housing, a plunger slidable in said housing and engagable with said control element to define a chamber therebetween, said chamber communicating with said second port, a spring biasing said plunger into engagement with said element, said element being movable against the bias of said spring in response to a pressure in said delivery passage which is less than the pressure required to lift said relief valve.

When a fluid flow control valve is used as a metering valve in a gas turbine engine fuel control system there is commonly provided a separate valve which is opened as the metering valve is shut, to return high pressure fuel to a drain line, thereby to reduce system pressure. It is desirable to reduce the amount of fuel discharged to the drain line, to minimise either the size of a drain tank, or the quantity of fuel discharged overboard. It is a further object of the invention to provide a fuel metering valve which incorporates means for reducing system pressure when the valve is shut.

According to a still further aspect of the invention a metering valve arrangement for regulating fuel flow from a pressure source to a gas turbine engine comprises a body having an inlet, an outlet and a return pressure port, and a control element movable within said body to regulate flow between said inlet and said outlet, said control element having a portion which uncovers said port to connect the latter to said

outlet in a closed condition only of said control element in which flow between said inlet and said outlet is prevented.

In a particular embodiment said valve arrangement includes a flow restrictor in series between said pressure source and said outlet, whereby in said closed condition said pressure source is connected to said return pressure port.

An embodiment illustrative of the inventions will now be described by way of example only and with reference to the accompanying drawings in which:-

Figure 1 is a block diagram of a control system for a gas turbine engine reheat fuel supply,

Figures 2, 3, and 4 show details of metering arrangments for respective groups of reheat burners of the engine, and forming parts of Figure 1,

Figure 5 is a detailed view, to an enlarged scale, of parts of the devices of Figures 2 and 3,

Figure 6 shows a pressure control valve forming part of Figure 1, and

Figure 7 shows a device for supplying a measured quantity of fuel for igniting the reheat burners.

The gas turbine engine 10, shown in Figure 1, has three groups of reheat burners, designated primary, bypass and core burners respectively. Fuel for these burners is supplied from a tank 11 by way of metering arrangements 12, 13 and 14 respectively. Outlet passages 15, 16, 17 for the arrangements 12, 13, 14 respectively pass to the engine 10 by way of an arrangement of spring-loaded shut-off valves 18. These valves 18 lift open at a predetermined pressure difference and act, in a manner to be described, as pressure relief valves during shut down of the reheat

system. The arrangements 12, 13 and 14 are shown in more detail in Figures 2 to 4 respectively and are responsive to signals from an electrical control circuit 20. A device 21 is also responsive to control signals from the circuit 20 to deliver a measured quantity of fuel on a line 22 to the engine 10 to transfer flame from the engine combustion chamber to the reheat burners when the reheat system is switched on.

The metering arrangements 12, 13, 14 receive fuel on a common supply passage 23 from a centrifugal pump 24 by way of a valve 25 which is biassed to connect the outlet of the pump 24 to a drain line 19, and is responsive to a predetermined level of delivery pressure from the pump 24 to connect the pump outlet to the passage 23 and to shut off the drain line 19. A low pressure pump 26 supplies fuel from the tank 11 to the inlet of the pump 24 by way of a line 34 and an electrically operated valve 27. A low pressure return line 28 communicates with the inlet of the pump 24 by way of a non-return valve 29. As shown in Figure 4 the arrangement 14 includes a filter 30 from which high pressure fuel is supplied from the passage 23 to a line 31. A manually operable valve 32 in a line 33 between the tank 11 and the inlet of the pump 26 is shut when the engine 10 is shut down. The pump 26 also supplies fuel on the line 34 to a main metering system 35 which includes a shut-off valve arrangement 36, the system 35, including the arrangement 36, being responsive to signals from the circuit 20.

As shown in Figure 2 the arrangement 12 includes a metering valve 40 having an inlet communicating with the passage 23 and a control element 41 for regulating flow between the passages 23 and 15. The element 41 is axially movable in response to a difference between

servo-pressures in chambers 42, 43, these pressures being derived at ports 66, 67 by a flapper-controlled pilot valve 44 from the high and return pressures in lines 31 and 28 respectively. The flapper 68 of the valve 44 is biased to a null position by springs 45, 46.

The valve 44 communicates with the chamber 42 by way of a line 39 and parallel pressure relief valves 47, 48 which permit flow in respective opposite directions. The valves 47, 48 are set to lift at a low pressure difference, for example 138kPa, which is nevertheless above the servo-pressure difference in the null condition of the valve 44. The springs 45, 46 are adjusted so that the difference between the pressure in line 39 and the pressures in chambers 42, 43 is very small when the valve 44 is in its null condition. The difference between the pressures in chambers 42, 43 is also very small when the valve 44 is operating, and in the steady-state condition of the valve 40 those pressures are substantially equal. The valve 44 is movable in either direction from its null position by a torque motor 50 which is controlled by the circuit 20 (Figure 1). Thus, if the valve 44 adopts a null position as a result of failure of the motor 50 or its electrical supply, the servo-pressure difference across the valve 47, 48 will be insufficient to lift either of them and the element 41 will move from its position only as a result of a very slow leakage to or from the chamber 42, this leakage being through the gap in a piston ring 38. A stem on the control element 41 is coupled to a displacement transducer 52 which signals the position of the element 41 to the circuit 20. An adjustable restricted orifice 51 is located between the high pressure line 31 and the outlet port 53 of the valve 40, to provide compensation for manufacturing tolerances in the profile of the metering orifice 69 of the valve 40.

The outlet 53 of the valve 40 communicates with the passage 15 by way of a pressure drop regulating valve 54 whose control element 55 is biassed open by a spring 37 and is responsive to pressure in a chamber 56 between a variable orifice 57 in the element 55 and a fixed restrictor 58. Flow through the orifice 57 is controlled by a piston 59 which is responsive to difference between the pressures in the outlet 53 and in the high pressure line 31, and is spring-loaded to shut the orifice 57. The valve 54 is dimensioned to provide a predetermined metering pressure drop across the valve 40, and regulates flow to the passage 15 to maintain that pressure drop constant. In use therefore the valve 54 maintains a constant pressure drop across the valve 40. The pressure in the outlet 53 is applied to the metering arrangement 13, 14 through lines 60, 61 respectively. The valve 40 includes a port 49 through which fuel can flow to the return line 28 from the outlet 53 when the valve 40 is shut. The valve 29 (Figure 1) allows this fuel to flow to the line 34 only when the pressure in line 28 is higher than that in line 34.

The arrangements 13, 14 are shown in Figures 3 and 4 and are generally similar to the arrangement 12, except in the sizes of their respective metering valves 62, 63, and will not be described in detail. The principal difference in the arrangements 13, 14 resides in their pressure drop control valves 64, 65 respectively, which are responsive to the pressure downstream of the valve 40, applied through the lines 60, 61. The valves 64, 65 are also responsive to the pressures downstream of the metering valves 62, 63. respectively. The arrangement is such that the pressures downstream of the valves 62, 63 are maintained equal to that downstream of the metering valve 40. Since the metering valves 40, 62, 63 have a

common supply passage 23, the pressure differences across all of the metering valves are maintained equal to each other.

The valves 64, 65 are shown in more detail in Figure 5. The valve 64 includes a sleeve 70 having ports 71 which communicate with the outlet passage 16. A control element 72 is slidable in the sleeve 70 and is urged towards a shut position by a spring 73. The sleeve 70 has a further port 74 which communicates by way of an annular passage 75 and a line 76 (see also Figures 1, 3 and 4) with a valve 77 (Figure 1) which provides constant reference pressure in the line 76. The sleeve 70 has an annular groove 78 which communicates with one of the ports 71. When the valve 64 is shut a further annular groove 79 in the element 72 interconnects the port 74 and the groove 78. In the shut condition of the valve 64 fuel can flow from the valve 77 (Figure 1) through the line 76, passage 75, port 74 and grooves 78, 79 to apply the reference pressure to the outlet passage 16.

In its shut condition the valve 65 can supply the reference pressure in line 76 to the passage 17, and corresponds to the valve 64 except that the control element 80 of the valve 65 has an additional port 81 through which leakage flow from the groove 79, between the control element 80 and its surrounding sleeve, can enter the bore of the valve 65 and pass to the line 61. As described above the line 61 communicates with the line 60 and with the outlet 53 of the valve 40 (Figure 2). Since the valve 54 is biased open, when the reheat system is in its shut down condition fuel from the line 61 can enter the outlet passage 15. With the reheat system shut down the valve 27 is shut and valve 25 (Figure 1) is connected to the drain line 19, though the pumps 24, 26 continue running. The

reference pressure in line 76, and applied to passages 15, 16, 17 is less than that at which the valves 18 (Figure 1) will lift, so that when the reheat system is shut down no fuel reaches the reheat burners. When the reheat system is operated to shut the valve 62 (Figure 3) and supply fuel to the primary and core burners only, the valve 64 also shuts and the reference pressure is applied to passage 16.

When the main fuel system and reheat system (Figure 1) are shut down, the shut-off valve arrangement 36 and the valves 27, 32 will be shut. Fuel is therefore trapped in the lines 33, 34, 85, 86 and pump 26. Heat flow from the engine 10, or an increase in ambient temperature may expand the trapped fuel and result in damage to those parts of the system. The valve 77, in addition to providing the reference pressure in line 76, also serves to prevent unacceptable pressure rise in the low pressure zones of the fuel system.

The valve 77 is shown in detail in Figure 6 and comprises a housing 98 including a valve sleeve 82. The sleeve 82 has first and second ports 83, 84 which communicate by way of respective lines 85, 86 with the outlet and inlet respectively of the pump 26 (Figure 1). A further port 96 also communicates with the line 86. A piston control element 87 has an axial blind bore 88 which communicates with an outlet to the line 76. The element 87 is biassed upwardly, as viewed in the drawing, by an evacuated spring bellows 89 which is secured to the housing 98 and to a plunger 90 which is sealingly slidable in the bore 88. The plunger 90 has a stem 91 engageable with the element 87. A chamber 92 containing the bellows communicates with the line 76 through a passage 93, so that both ends of the element 87 are subjected to the pressure in line 76. A volume

94 defined within the bore 88 by the plunger 90 communicates with the port 84 by way of the port 96 and a recess 95 in the sleeve 82. The element 87 overlaps the ports 83, 84 so that only one of the ports 83, 84 communicates with the line 76 at one time.

In use, fuel will initially flow from the line 85 to the line 76 through the port 83 and passage 93. At a predetermined level of pressure in the line 76, determined by the spring loading of the bellows 89, the element 87 moves to shut the port 83 and uncover the port 84, interconnecting lines 76 and 86. If the pressure in line 76 falls the element 87 reconnects the port 83 to line 76. The arrangement thus provides a regulated reference pressure in line 76 for priming the supply passages 15, 16, 17 while the reheat system is shut down. After priming the line 76 and elements downstream thereof are full of fuel, and both of the ports 83, 84 are shut. Since the reference pressure in line 76 is less than that at which the valves 18 (Figure 1) will open, no fuel flows to the reheat burners. Fuel upstream of the valves 18 is maintained at a pressure sufficient to prevent boiling.

In the shut-down condition of engine heat may cause fuel in the lines 33, 34, 85, 86 and in the pump 26 (Figure 1) to expand. A rise in pressure in line 86 enters the volume 94 in the valve 77. If this pressure exceeds the reference value set by the bellows 89 for the line 76, the plunger 90 moves downwards, as viewed in the drawing. The element 87 is thus urged upward by the pressure in line 86 only, interconnecting lines 76 and 85. Any rise in pressure in the line 86 will be accompanied by a corresponding rise in the pressure in line 85 from the pump outlet. The resulting rise in pressure in line 76 will cause the valves 18 to open, limiting the pressure in line 76 and in the passages

15, 16, 17 to just above the reference pressure.

The device 21 shown in Figure 7 comprises a spool valve 100 and a change-over valve 101 operated by a solenoid 102. High pressure in line 31 is applied to a port 103 of the valve 100. A further port 104 and a chamber 105 at one end of the valve spool are connected to the low pressure return line 28. A chamber 106 at the other end of the spool is connected by the valve 101 to the return line 28 when the solenoid 102 is de-energised or to the high pressure line 31 when the solenoid 102 is energised on selection of reheat. The spool is biased by a spring 107 to connect the port 103 to a chamber 108 in which a piston 109 is slidable. The piston 109 is biased by a spring 110 to provide a maximum volume in the chamber 108 and the spring bias is opposed by the pressure in a chamber 111 which, in the de-energised condition of the solenoid 102 is connected to the low pressure line 28 through the port 104 and a port 112. In this condition the line 22 to the engine 10 is shut-off and the chamber 108 is charged with fuel from the line 31 through port 103 and a further port 113. The piston 109 is maintained in its charged position by the spring 110, in the absence of pressure in line 31, when the reheat system is shut down.

At reheat start-up after fuel flow to selected ones of the reheat burners has been established, the solenoid 102 is energised to apply the high pressure in line 31 to the chamber 106, moving the spool against the spring 107 to the full extent of its travel, as determined by an abutment 114, in which position the chamber 108 is isolated from line 31 and connected to line 22. At the same time the high pressure line 31 is connected to the chamber 111 through ports 103, 112, and the piston 109 moves to expel fuel in the chamber

108 to the line 22, through the ports 113, 115. The fuel so expelled passes to the engine combustion chamber and a location downstream thereof, resulting in a streak of flame between the combustion chamber and the selected burners, to ignite fuel at the latter.

When the reheat system is shut down, the valves 40, 62, 63 (Figures 2, 3 and 4) are shut. The pump inlet valve 27 (Figure 1) is also shut, but the valve 25 continues to pass fuel to the passage 23 while the pump 24 empties, maintaining servo operating pressure on the line 31. In the fully shut conditions of valves 62, 63 the pressuresupstream of valves 64, 65 respectively (Figure 5) are lower than that in lines 60, 61, so that valves 64, 65 shut, stopping flow to the passages 16, 17 and establishing the reference pressure in those passages, as described above. In the shut condition of valve 40 the low pressure return port 49 therein is open and fuel flows from the line 31 to the return line 28 through the restrictor orifice 51, line 61 and port 49. The pressure drop between passage 23 and outlet 53 is greater than the predetermined metering pressure drop of valve 54, and that valve moves to reduce the pressure drop, shutting off flow to the passage 15. As the pump 24 empties via the orifice 51 and port 49 (Figure 2), and their equivalents in the arrangements 13, 14, the pressure in line 31 falls to that in the return line 28, at which pressure in the line 31 the valve 25 connects the outlet of the pump 24 to the drain line 19. The low pressure in line 31 results in absence of servo pressure for the valve 54, which opens under influence of its spring. Reference pressure in line 76, which has already been established in passages 16, 17 is established in passage 15, as described above.

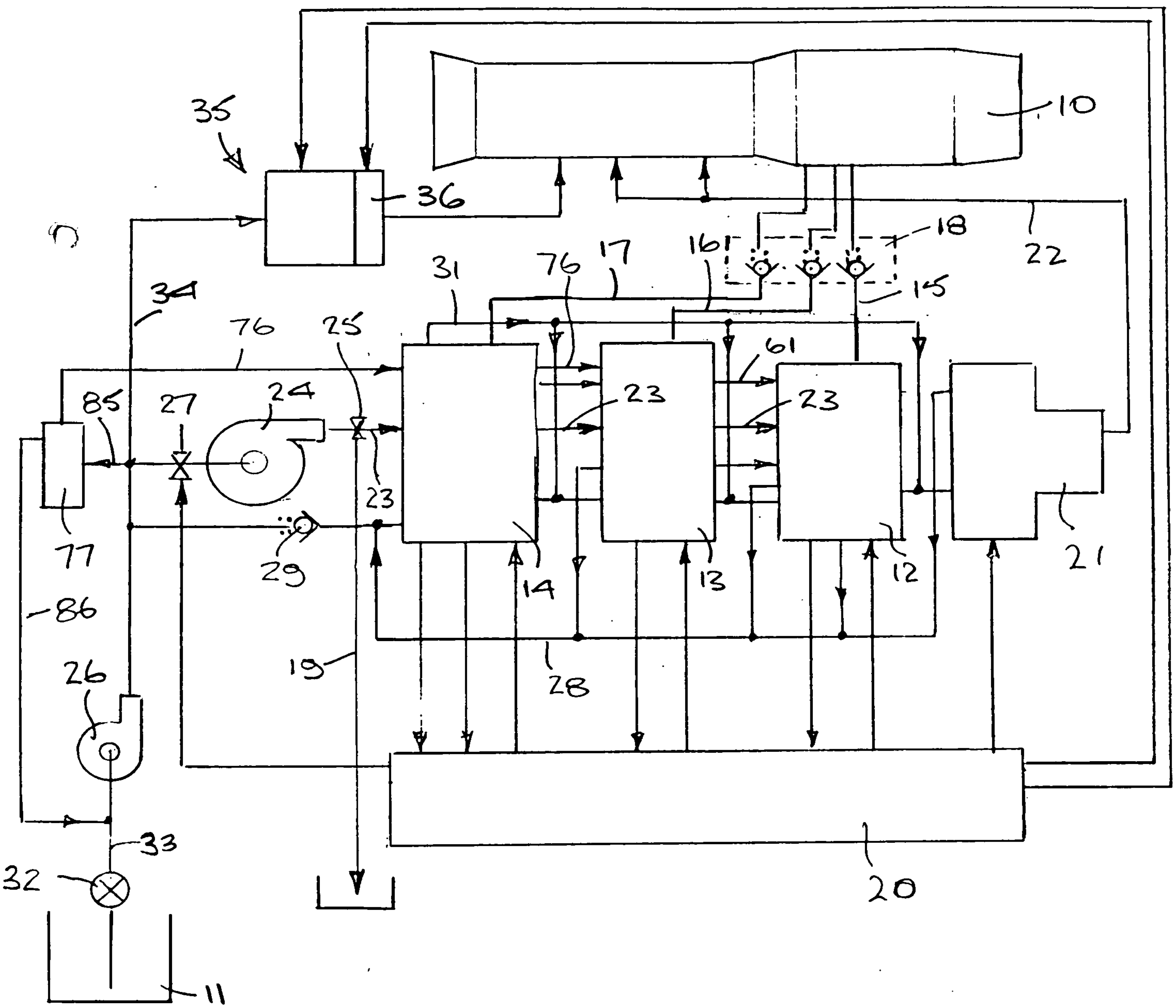
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FIG. 1

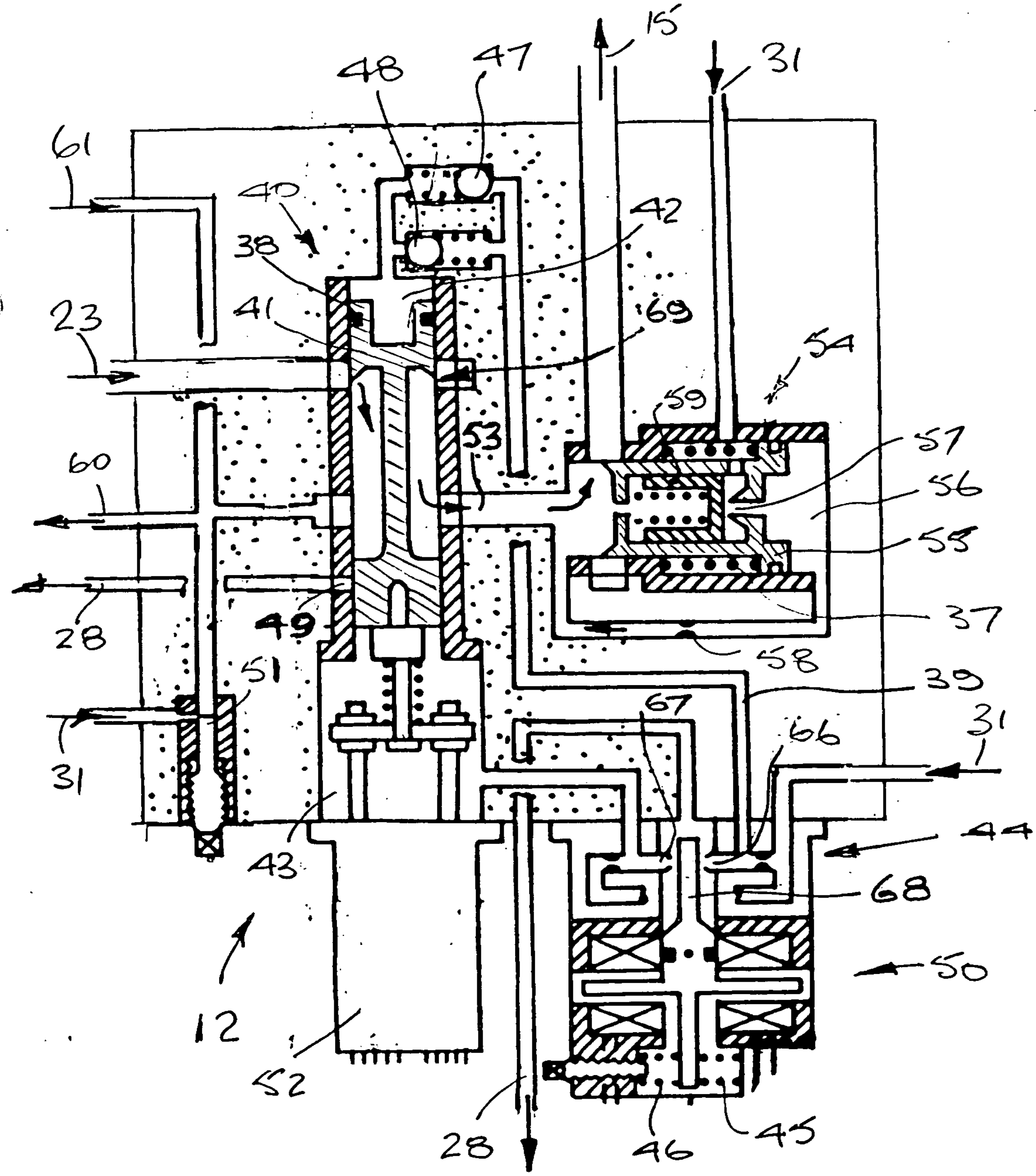
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FIG. 2

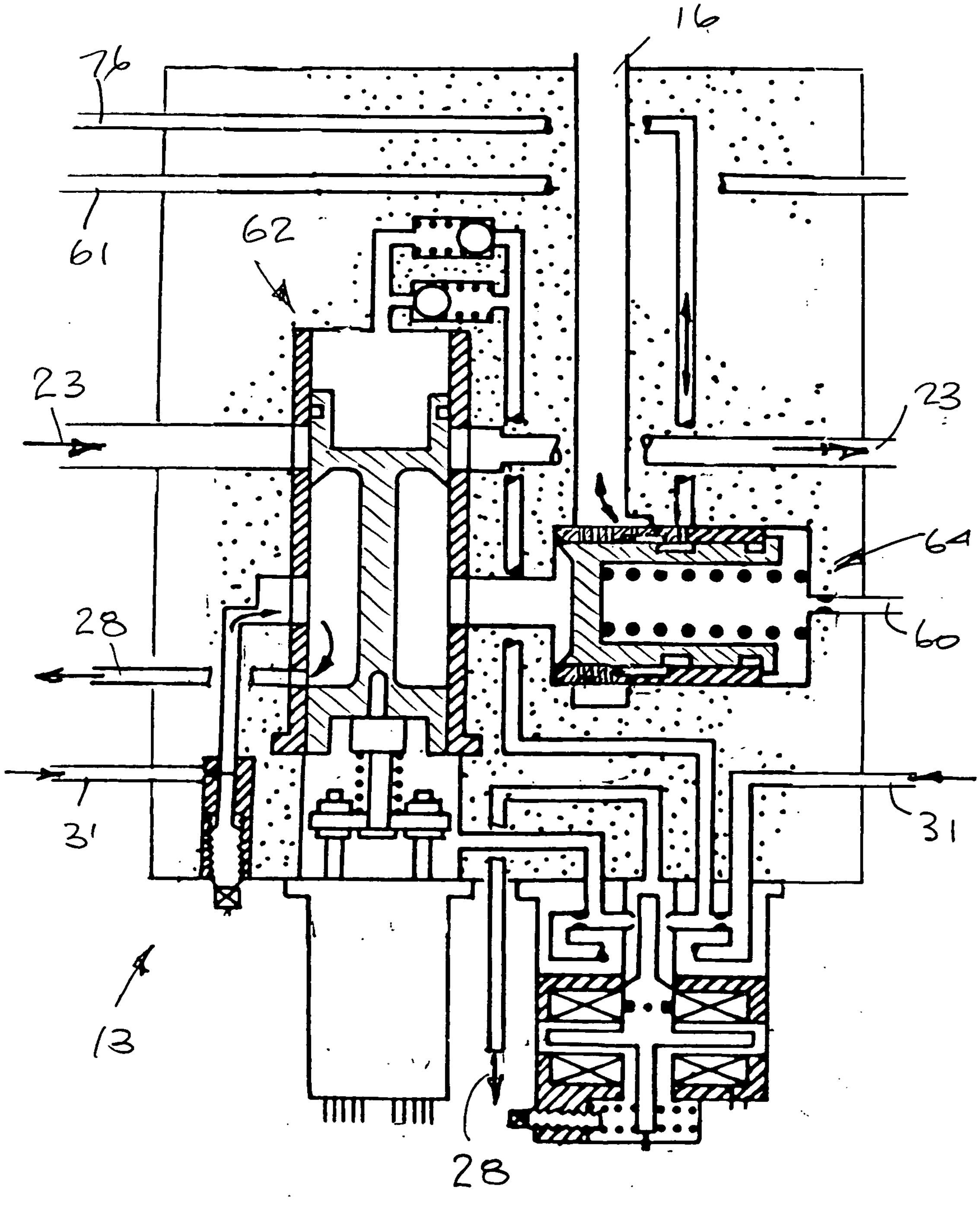

FIG. 3

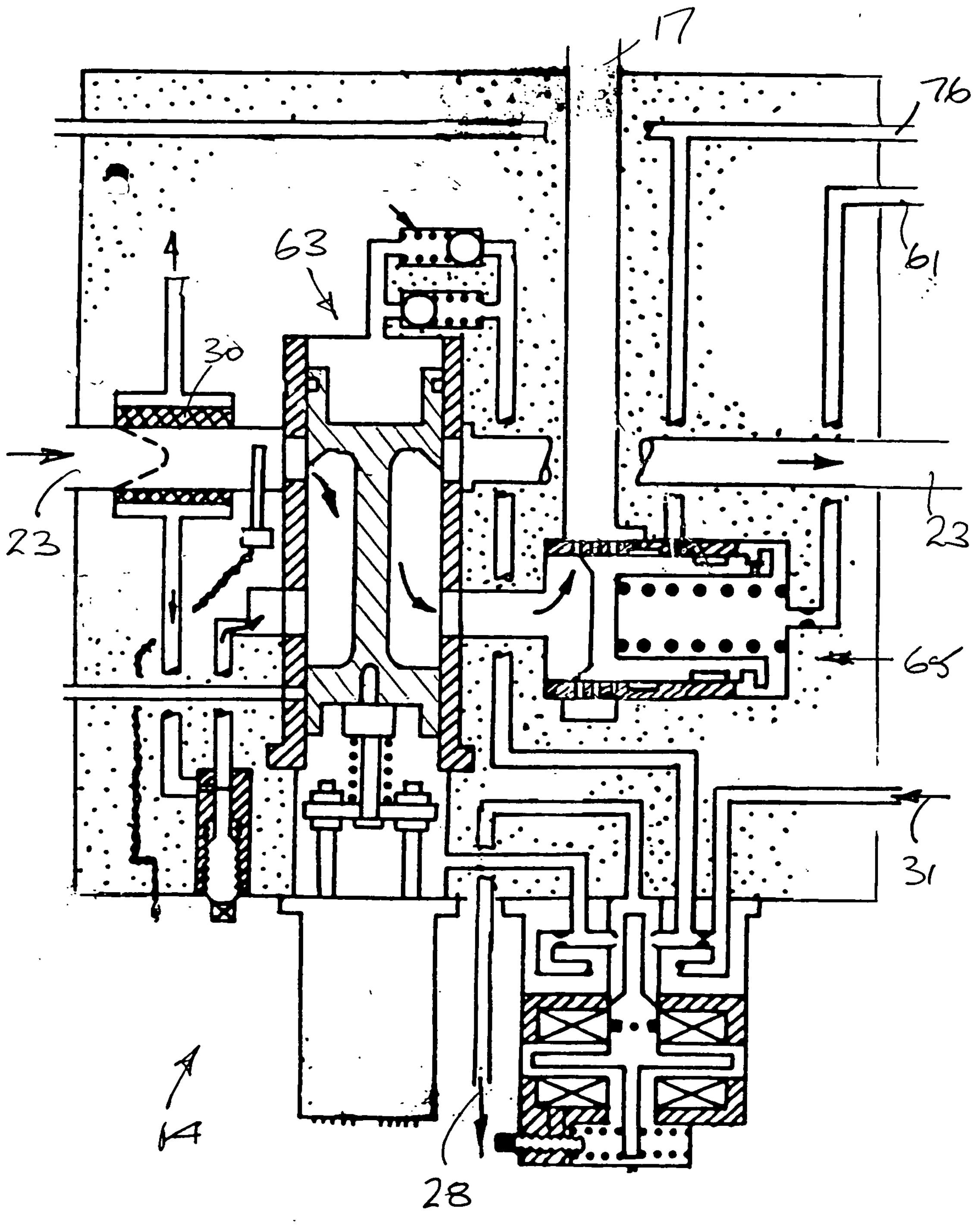

FIG.4

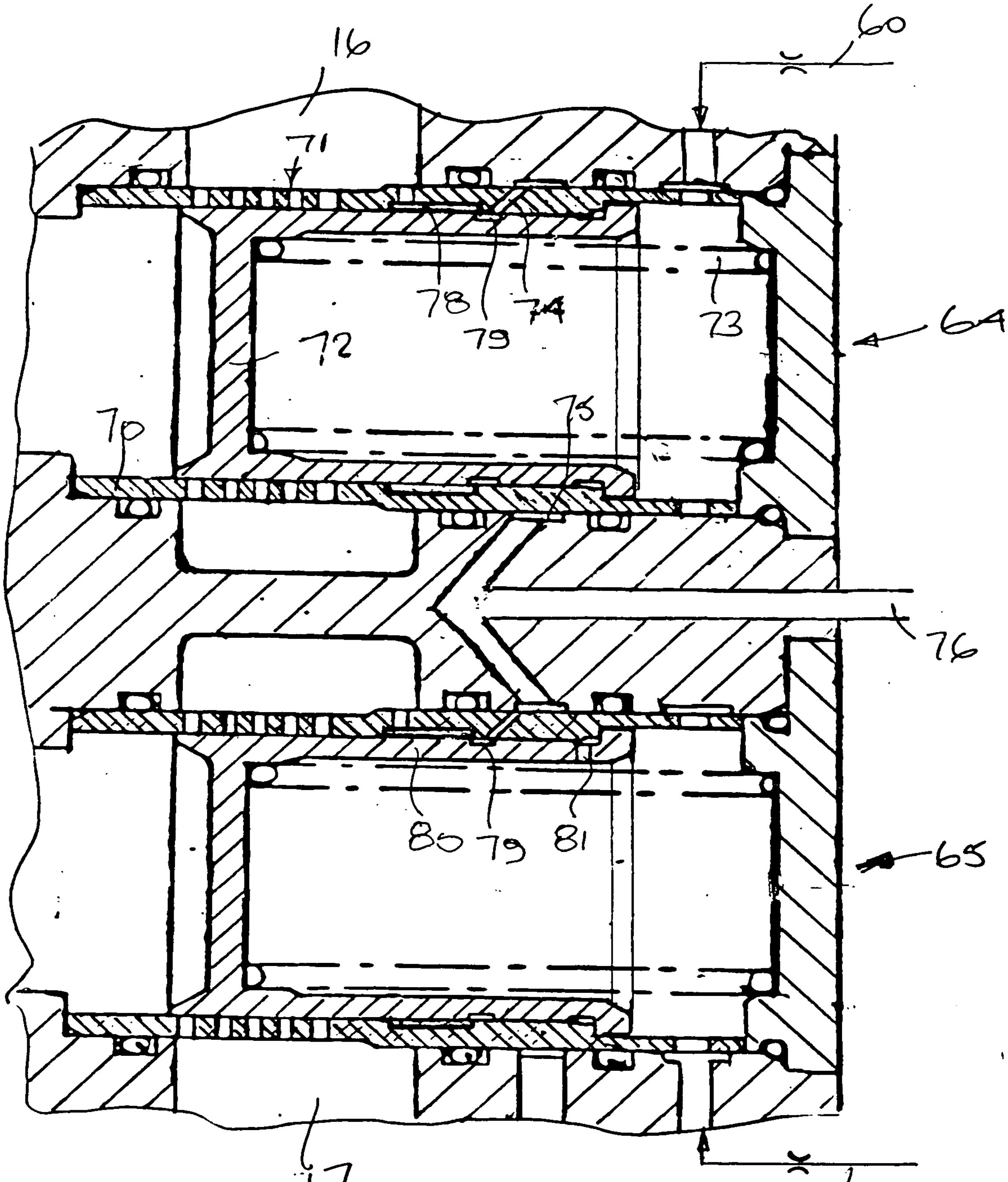

FIG. 5

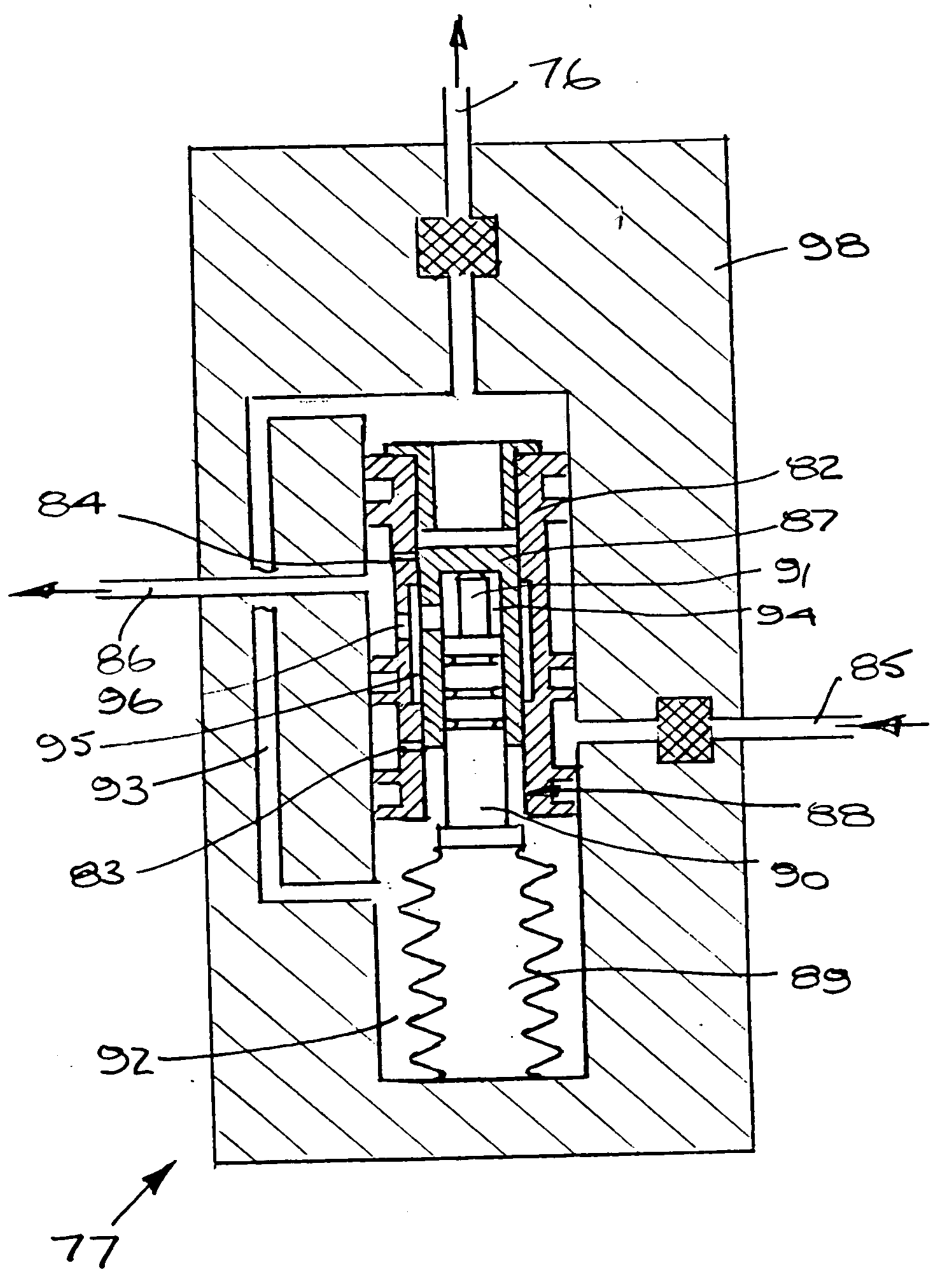

FIG 6

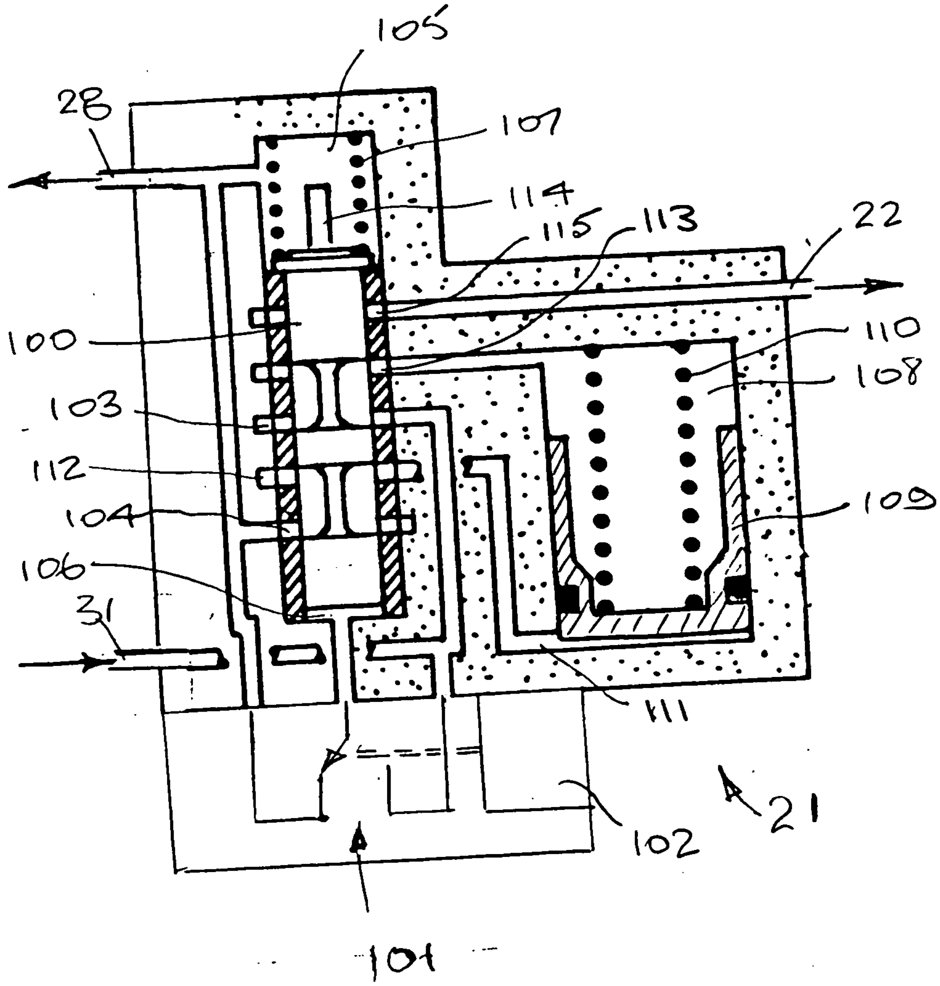
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FIG. 7